



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION 6

1445 ROSS AVENUE, SUITE 1200
DALLAS, TEXAS 75202 - 2733

SEP 22 2016

Mr. Tim Baker, Director
Oil and Gas Conservation Division
Oklahoma Corporation Commission
P.O. Box 52000-2000
Oklahoma City, OK 73152-2000

Dear Mr. Baker:

Enclosed is our evaluation of Oklahoma's Class II Underground Injection Control (UIC) program performance during state fiscal 2015 (FY15). The Environmental Protection Agency (EPA) representatives met to discuss EPA's annual end-of-year evaluation with the Oklahoma Corporation Commission (OCC) management on December 7, 2015 along with ongoing discussions and e-mails throughout the year. By e-mail on July 13, 2016, we invited OCC's comments on the draft evaluation and OCC responded with no comments on August 5th.

We thank you and your staff for your efforts in the implementation of this challenging program. We consider our open dialogue a key component of effective communication between our agencies. If you have any questions on the evaluation report or the revision requests, you may contact me at (214) 665-7101, or your staff may call Philip Dellinger of my staff at (214) 665-7150.

Sincerely,

A handwritten signature in blue ink, which appears to read "WK Honker", is positioned above the printed name of the signatory.

William K. Honker, P.E.
Director
Water Division

Enclosure

cc: Patricia Downey, OCC UIC Manager, w/encl.

**EPA Region 6
End-Of-Year (EOY) Review**

**Oklahoma Corporation Commission (OCC)
Underground Injection Control (UIC) Program**

**State Fiscal Year 2015 (SFY2015)
July 1, 2014 through June 30, 2015**

INTRODUCTION

EPA has approved the Oklahoma Corporation Commission (OCC) as the primary enforcement agency for the State's Class II injection wells while the Oklahoma Department of Environmental Quality (ODEQ) implements the applicable State UIC program for all other injection wells in Oklahoma. EPA retains primary authority for Class I, III, IV and V on certain Indian Lands and Class II on some Indian Lands not under the authority of OCC. This annual review considers the approved State UIC program administered by OCC, including the UIC grant work plan and other program activities, between July 1, 2014 and June 30, 2015.

EPA representatives met to discuss EPA's annual end-of-year (EOY) evaluation with OCC management on December 7, 2015, along with ongoing discussions and e-mails throughout the year. (See Appendix A for attendees). Appendix B contains OCC's annual narrative required in the SFY2015 UIC grant work plan. This report covers the OCC 2015 fiscal year (July 1, 2014 thru June 30, 2015), with the exception of the topics of seismic activity and the OCC well database. These two main areas of concern were identified in EPA's previous program review released in September 2015. Detailed discussions related to ongoing seismicity and the OCC database include events through December 2015.

EPA's annual review for the SFY 2014 described developments related to the ongoing issue of seismic activity in Oklahoma. The report described recent research findings related to injection-induced seismicity, OCC response actions including injection volume reductions, and EPA's recommendations for additional action. Despite OCC's evolving response actions, seismicity continues to be of concern, particularly with respect to the upward trend in the number of Magnitude 4 and greater events (M4+) through 2015. This trend included a record monthly number of M4+ events in November 2015.

Until March 2016, OCC's response actions to reduce injection volumes focused on disposal wells in localized geographic areas defined by the location of M4+ events¹. EPA has learned that in some cases, OCC permitted restricted wells to return to normal operations and new wells authorized in targeted areas after requesting volume restrictions of existing wells. EPA has expressed concern that these inconsistencies are significantly diminishing the effectiveness of OCC's response actions. EPA is also concerned with OCC's permitting of tightly spaced or multi-leg horizontal disposal wells, which compound the pressure impact on the receiving formation, increasing the likelihood of additional fracturing and long-distance pressure buildup.

¹ There was also an early regional Area of Interest defined to collect daily operational reports, and the major effort to ensure the wells were not open below the Arbuckle Formation, discussed in Appendix G.

As indicated in the EPA/State report² on injection-induced seismicity, released in February 2015, pressure influences from disposal wells in fractured formations can extend miles away from the disposal well. The Arbuckle Formation is a fractured formation and localized response areas may not be of sufficient extent. In addition to providing avenues of pressure influence for lengthy horizontal distances, Arbuckle fractures likely communicate pressure increases vertically down to basement faults, and thereby significantly increase the risk of seismic activity.

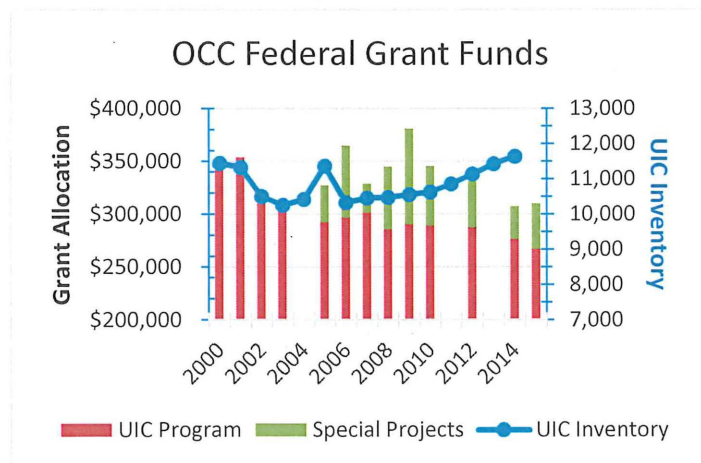
The level of seismic activity, especially the increasing trend of larger events, is of growing concern and warrants more action. EPA therefore strongly supports recent (February 2016) actions based on decreases in both the total and individual well volumes for any well injecting into the Arbuckle Formation in an expanded area of concern. EPA also recommends policy changes and/or promulgation of rules requiring consistent implementation of control area restrictions. Consistent with that position, EPA highly recommends the directives and actions covering the three current areas of reduction have full regulatory backing including appropriate enforcement authority. EPA continues to provide technical support to OCC regarding ongoing seismicity via an experienced geological engineer and GIS expert.

This report is broken into six main sections: Introduction, Grant Work Plan, Program Revisions, OCC Procedural Areas, UIC Oversight Issues, and Summary and Recommendations. Additional information is included in the appendices.

GRANT WORK PLAN

SFY2015 GRANT

OCC's SFY2015 application was for a total of \$468,595 in Federal funds. EPA approved \$267,000 as the Federal 2015 allotment for the State of Oklahoma's UIC program administered by the OCC, and awarded this amount to OCC in SFY2015. In addition, EPA awarded OCC \$42,906 in UIC Special Project funds in FY2015. This brings the total awarded to \$309,906 (\$267,000 + \$42,906). Work plan Deliverables—OCC submitted all required State program updates and other deliverables required during SFY2015.



During the EOY meeting, OCC made a plea for greater federal funding based on increased workload related to activity levels, particularly in the Alfalfa County oil and gas play, and to address the seismicity issue. As shown in Figure 1, the UIC grant allocation has gradually decreased over the last fifteen years, while inventory has significantly increased. OCC has also requested an increase in permit fees to cover the extra costs associated with tracking seismicity.

Figure 1: UIC Grant Allocation versus Inventory

² Minimizing and Managing Potential Impacts of Injection Induced Seismicity from Class II Disposal Wells: Practical Approaches; <http://www.epa.gov/uic/underground-injection-control-national-technical-workgroup-final-issue-papers>

SPECIAL PROJECTS

EPA commends OCC on their continuing commitment to improving their information resource database through Special Project initiatives, such as the geo-referenced archival aerial photos, and Document Imaging. The OCC Narrative in Appendix B describes the status of OCC's special projects for the year.

PROGRAM REVISIONS

OCC submitted updates for the Safe Drinking Water Act Section 1425 program to EPA on September 26, 2011. This submittal is pending EPA review. OCC continues to revise its directives to better manage the seismicity issue.

OCC PROCEDURE AND PUBLIC ACCESS

Like all state and federal agencies, OCC's UIC office has undergone numerous changes through advances in technology and personnel changes over the years. These changes have provided opportunities to review and modify existing procedures. All programs benefit from these reassessments, which are part of the basis of the Quality Management / Quality Assurance system that EPA requires of itself and all grantees.

RBDMS

According to the Ground Water Protection Council's (GWPC's) Risk Based Data Management System (RBDMS) website³, the original RBDMS design allowed tracking of UIC data, with the ability to allow regulators to expand the system to track other aspects of oil and gas regulation, such as well construction and inspection. As larger agencies started using RBDMS, the volume of incoming data dictated a significant upgrade to the system design—RBDMS.Net. The design of the revised database system still allows customization by the host agency.

EPA's 2014 EOY review described the pros and cons of OCC's RBDMS created through the GWPC. EPA commends OCC for persevering through the numerous obstacles while working to improve the data accuracy in the system. Discussions with OCC and GWPC staff following release of EPA's EOY report indicated the combination of significant data clean up completed by UIC staff, and updating the system to the newer e-forms will resolve the major issues identified in that report. At the December 2015 EOY meeting, OCC gave a presentation to demonstrate the current RBDMS.Net abilities, including revised forms and apps allowing the public to identify wells anywhere in the state.

However, while these actions should resolve issues such as missing well numbers and provide additional public access, EPA believes significant issues still remain. Specifically, concerns over underlying issues with required data fields, and successful data quality control are not addressed by these actions.

There are a number of specific causes for the remaining database issues. A detailed discussion of identified issues is presented in Appendix C. Some of the database issues result in significant impacts on fundamental UIC program requirements, and therefore affect the effectiveness of OCC's program. Examples include:

- Inability to reliably schedule Mechanical Integrity Tests (MIT, F1075)
 - This is a requirement to protect USDWs from malfunctioning injection wells.

³ <http://www/rbdmsonline.org/products/rbdms-classic/>

- OCC reported almost a 1000 fewer MITs conducted in FY15 than FY14. In mid-December 2015, OCC discovered that 40% of their 380 commercial disposal wells were overdue for MITs.
- Poor data reliability created two major parts of the MIT scheduling malfunction: 11,600 inaccurate well classifications and inability to track active permits and timing of well integrity tests (MITs, radioactive tracers or water levels in nearby wells).
- See Appendix C: Report to Schedule MITs.
- Inability to properly track disposal volumes and pressures (F1012)
 - This is an essential component in evaluating a well's pressure influence for both protection of the USDW and possible induced seismicity interactions.
 - Poor data reliability on submitted reports coupled with inadequate planning for future needs and lack of built-in quality control will continue to cause this issue.
 - See Appendix C: Fluid Injection Reports.
- Inability to properly locate all active or inactive wells (F1002A & F1075)
 - It is a basic program necessity to know where all wellbores are located in order to, among other things, identify proximity to unplugged wells (USDW protection) or basement faults extending up into the disposal zone (seismicity).
 - Poor data reliability coupled with inadequate planning for future needs and lack of built-in and quality control will continue to cause this issue.
 - See Appendix C: Other Procedural Issues.

EPA strongly recommends OCC place high priority on resolving the numerous issues with its database. Additionally, the ability to run reports for all standard UIC program needs or seismicity requests is vital. The ability to create reports for later needs is also important. Because this will require participation and cooperation of multiple parts of the organization, OCC senior management should push this effort.

EPA UIC OVERSIGHT ISSUES

EPA has expressed concerns with some aspects of the OCC permit process over the years. These concerns primarily focus on OCC's area of review process, financial surety requirements, permit stipulation tracking, and gaps in permit coverage. Although these issues remain of concern to EPA, resolution of RBDMS database issues and addressing areas of high seismic activity were higher priorities for SFY2015. A related issue of concern, highlighted during efforts to evaluate the effect of injection volumes, rates and pressures versus seismicity, is the question of reliability and availability of operator reported data.

OPERATOR REPORTS

Over the last several years, OCC has worked hard to improve operator compliance with mandatory filing requirements, such as the F1012 annual disposal/injection reports (on a monthly basis) and F1002A completion reports. With the initiation of more frequent (daily basis) reporting required for Arbuckle Formation or deeper completions in the seismically active areas of interest (AOI), tracking efforts have become significantly more time consuming. OCC, with suggestions from EPA staff, devised a spreadsheet method to facilitate both data collection and relatively quick analysis focusing on the AOI, name of operator and disposal activities. This is even more critical with the advent of the two large reduction areas defined in western and central Oklahoma.

The range of operator compliance improved, but problems still exist. EPA notes few enforcement actions taken by OCC for operators who do not meet the monitoring and reporting requirements. A number of operators continue to report questionable estimated numbers, i.e constant pressure and/or

rate with no basis. Others attempt to provide the information required, but field office verification issues produce erroneous results in the filed reports. Two examples include, produced water volumes piped directly to the disposal well do not match disposal volumes; the operator did not initially disclose the fact that the Wilzetta SWD well, implicated by various authors in the Prague M5.7, was in fact open to basement rock. OCC's actions in the above instances have apparently been limited to discussions with operators or requested corrections to the appropriate forms with no other repercussions. For complete details, see Appendix D.

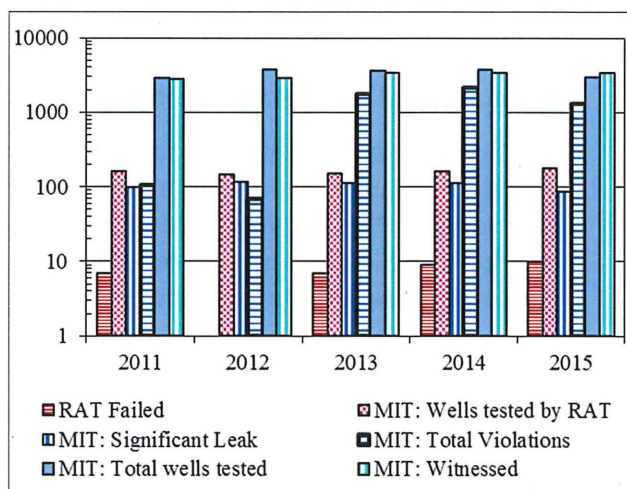


Figure 2: Mechanical Integrity Tests

MECHANICAL INTEGRITY TESTS (MIT)

OCC continues to conduct and witness (Appendix B) annual mechanical integrity tests for well over 20% of the inventoried injection wells. This is indicative of OCC's success at meeting the minimum five-year MIT requirement for all wells in the inventory. EPA again commends OCC for this accomplishment, and for witnessing the majority of the MITs. EPA also commends OCC for establishing more frequent testing requirements on high injection volume wells. High volume wells ($\geq 20,000$ BPD) must now have an MIT annually, instead of every five years. Figure 2 shows the number of MIT's witnessed, and the number of site inspections. Issues with RBDMS functionality required OCC staff to reenter the data twice in order to track the MIT activity.

ENFORCEMENT ACTIONS

Figure 3 provides a summary of OCC enforcement actions. The absence of Monitoring and Reporting entries for years 2013 through 2015 represents a failure of RBDMS to provide required information.

SEISMICITY

OCC continued to focus significant amounts of UIC staff time to track and evaluate ongoing seismicity, and verify that no disposal wells in the seismically active area penetrate below the Arbuckle Formation. Handling the daily pressure and volume information on wells required to submit daily information and verifying operator compliance with requests to shut-in or reduce volumes are additional resource drains at a time the OCC's budget was further cut. More recently, funds for temporary staff to deal with some of the additional workload came through the Oklahoma Secretary of Energy and Environment's office.

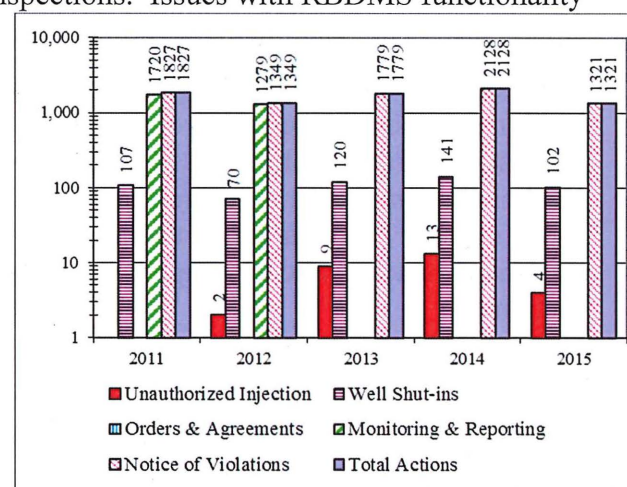


Figure 3: Enforcement Actions

Information Requirements

Accuracy of the typical UIC well information collected becomes extremely important when attempting to analyze potential interactions between well operations and seismicity. This information includes accurate locations (surface, lateral locations and bottom hole), completion intervals, packer depth and tubing size, order or permit details, accurate injection volumes and

pressures for the required time period (daily or monthly), date disposal initiated, mechanical integrity and workover timing. Keeping this information up-to-date and accurate requires operator compliance, staff time and a workable database.

Additionally, the Oklahoma Geologic Survey (OGS) resources are essential for providing all seismological information and interpretations, as well as for additional geoscience support. The OGS seismometer network permits significantly better coverage for seismicity across the state than the USGS backbone network, though the two do share information. Appendix E lists the OGS earthquake events at or above magnitude 4, through the end of 2015.

Seismologic Data Sensitivity

All geoscience interpretation contains a subjective element. The complete relocation process, necessary to provide accurate event locations and magnitudes, includes hand picking the seismic elements from the monitor readings, collecting citizen-felt responses, refining the geologic thicknesses and parameters and then running models to analyze the data. Recalculating locations (longitude, latitude and depth) provides more accuracy, but can take a year or more to finalize. OCC therefore must use initially gathered locations and magnitudes in its day-to-day efforts and this presents problems in OCC's implementation of response actions. Appendix F provides more detailed information on this issue.

OCC Directives and Actions with respect to Seismicity

OCC continues to modify its traffic light system and other response strategies to address ongoing seismicity in Oklahoma. Figure 4a shows the variability of daily earthquake events based on the OGS preferred magnitudes; Figure 4b shows the timing of OCC actions or directives in response to the seismicity, along with the timing of wells plugged back into the Arbuckle.

Appendix E covers a summary of the OCC directives and actions shown in the above figure, with respect to seismicity that occurred in 2015, through the end of November. For a time it appeared that the combination of the increased area of interest (AOI) and plug-back efforts were reducing seismicity. However, seismicity again increased in mid-July including a number of M4+ events. The variation in the number of daily seismic events (Figure 4a) suggests the seismicity is too cyclic to compare in the short term with the timing of OCC and operator actions.

Better analysis would incorporate the effect of cumulative disposal volumes and subsequent formation pressure increases. In fact, OCC staff have created and evaluated numerous plots of seismicity versus disposal volumes. To date, OCC has not included this operational analysis as part of any published actions.

OCC's response plan on December 1, 2015 depended on the number and timing of magnitude 4 or greater events within the same AOI.

1. One \geq M4 event
 - a. Arbuckle wells within 3 miles reduce disposal volume by 50%.
 - b. Arbuckle wells between three and six miles reduce disposal volume by 25%.
 - c. Operators of Arbuckle wells between six and ten miles are on notice of potential changes if seismicity continues.
2. Two \geq M4 events, excluding aftershocks
 - a. Arbuckle wells within 3 miles are shut-in.
 - b. Arbuckle wells between three and six miles reduce disposal volume by 50%.

- c. Operators of Arbuckle wells between six and ten miles reduce disposal volume by 25%.
- d. Operators of Arbuckle wells between ten and fifteen miles are on notice of potential changes if seismicity continues.

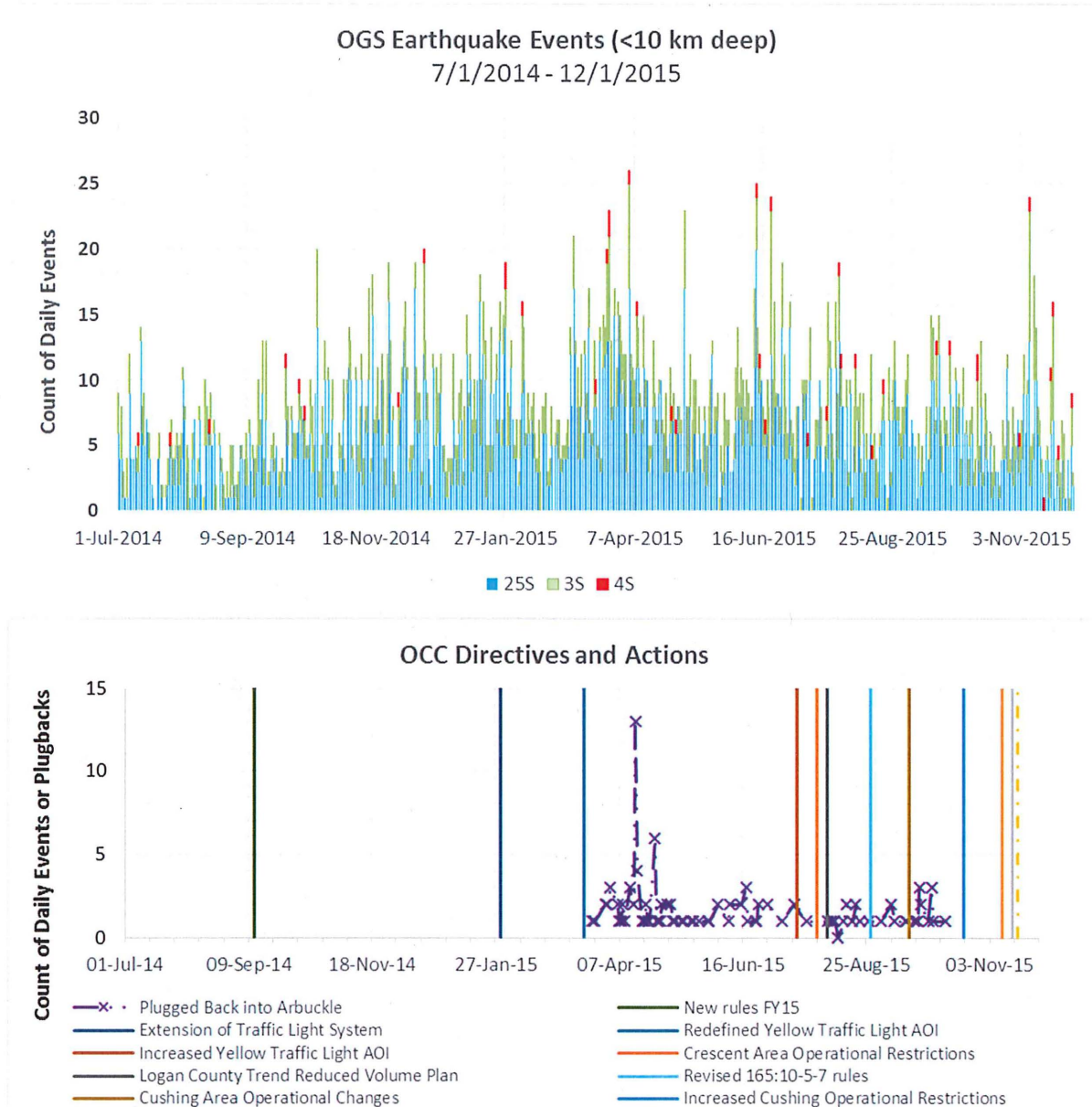


Figure 4: Seismicity and Actions

EPA Analysis of OCC Response Strategies

The federal Class II UIC program does not have regulations specific to seismicity but includes discretionary authority that allows additional conditions to be added to the injection permit on a case-by-case basis, along with additional requirements for construction, corrective action,

operation, monitoring, or reporting (including closure of the injection well) as necessary to protect USDWs⁴.

The OCC instituted a traffic light system in 2013 requiring disposal applications in seismically active or potentially seismic active areas to go through the Commission's court system. EPA identified over 20 disposal well applications that were approved in restricted areas under this system and one denial.

Figure 5 illustrates the geographic scope of OCC earthquake actions (voluntary and administrative). The appearance may be the result of OCC's ongoing process to reduce seismicity, starting with the most obvious opportunities (attempts of getting disposal out of the basement and changing from permits to interim orders) to adjusting disposal volumes in key areas. From January 2013 until issuance of the first (March 25, 2015) AOI, each Magnitude 4 was evaluated by itself. Following the Cushing events described above the focused area method was reinstituted on October 19th. The unlabeled 10-mile buffers represent earlier M4+ events—without actions, possibly a result of revised seismic event reports.

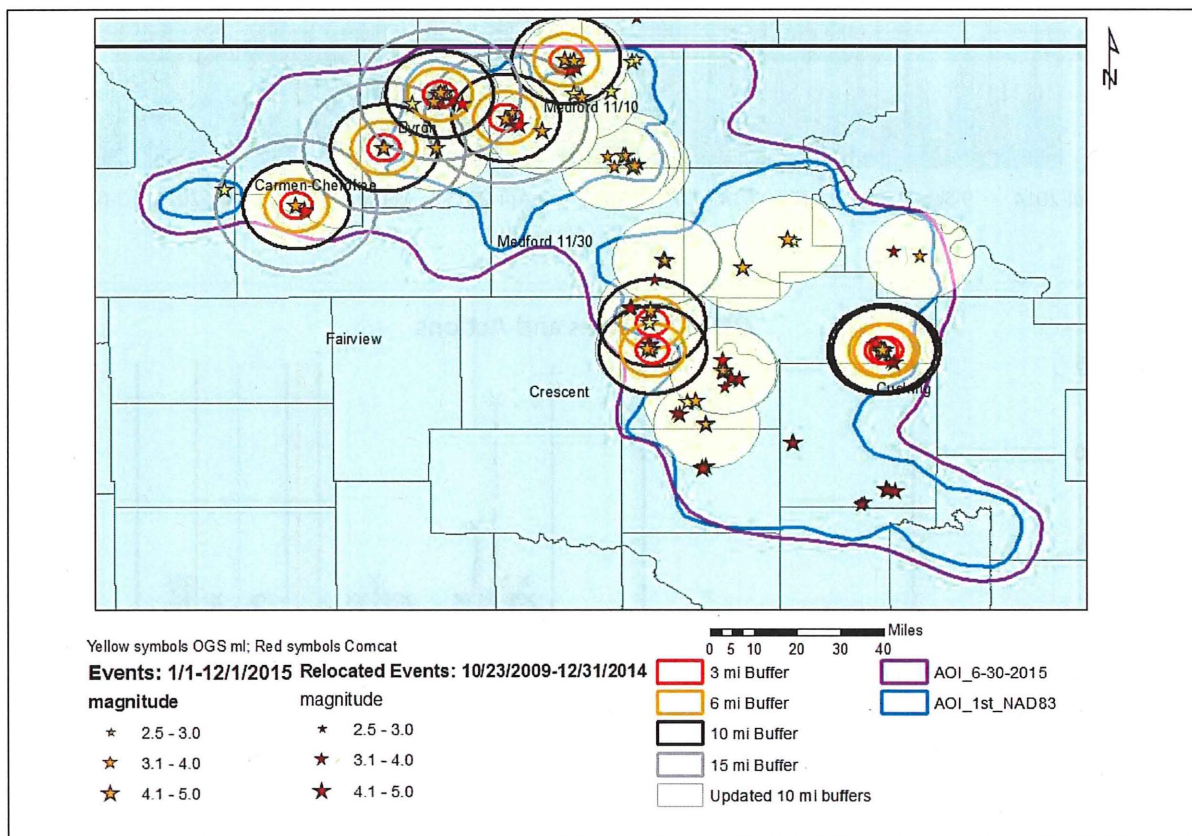


Figure 5: OCC AOIs

OCC used the most stringent restriction when a well was located in one or more M4+ Areas of Interest.

Two other issues of concern with the process of reducing seismicity include the addition of new Arbuckle disposal wells and the delayed or unspecified timing of reduced rates.

⁴ 40 CFR §144.12(b); 40 CFR §144.52(a)(9) or (b)(1); or appropriate section of 40 CFR Part 147.

1. Only the Interim Order traffic light process can deny a new Arbuckle permit in a seismically active area, including those areas experiencing cutbacks of disposal volumes.
2. Several of the OCC actions contained rate reductions or requests to plug-back out of the Arbuckle, but contained no compliance deadline.

Public Actions

A growing number of legal actions are being filed in response to the ongoing seismicity.

SUMMARY AND RECOMMENDATIONS

Two major issues continue to impact the OCC UIC program, database limitations and seismicity. EPA's review focused in detail on these two issues.

EPA commends OCC and GWPC for developing a new user interface for the RBDMS database to allow better public usability, and significant OCC staff efforts to clean up existing data problems. EPA recommends the following to address ongoing database issues:

- High level organizational support to improve the functionality of the existing database.
- Database modification should focus on quality control measures for data input. Specific recommendations in this regard are in Appendix C.
- Attention should also be given to standard report generation for reports required in the UIC program.
- Continue efforts to clean up remaining data problems.

EPA commends OCC on its recent actions to institute large scale volume restriction areas and recommends that OCC implement additional regulatory actions to assure protection of Underground Sources of Drinking Water (USDWs) from seismic activity, including further reduction of injection volumes into the Arbuckle disposal formation in seismically active areas. EPA also recommends the following related to seismicity:

- Ongoing increasing seismicity trends despite OCC's actions to plugback basement penetrations indicate hydraulic connection between the Arbuckle Formation and basement rocks. Therefore, EPA recommends OCC consider a moratorium on Arbuckle disposal in high seismically active focus areas.
- OCC should implement policy or program changes to prevent new Arbuckle injection activities in restricted areas.

**APPENDIX A: State/EPA UIC Meeting
December 8, 2015
Staff in Attendance**

NAME	AGENCY	PHONE
Mr. Tim Baker	Oklahoma Corporation Commission	(405) 522-2763
Ms. Patricia Downey	Oklahoma Corporation Commission	(405) 522-2745
Mr. Charles Lord	Oklahoma Corporation Commission	(405) 522-2751
Mr. James Brown	Environmental Protection Agency	(214) 665-3175
Mr. Philip Dellinger	Environmental Protection Agency	(214) 665-8324
Ms. Nancy Dorsey	Environmental Protection Agency	(214) 665-2294
Attended for only part of the meeting		
Mr. Jim Marlatt	Oklahoma Corporation Commission	(405) 522-2758
Ms. Laura Erichsen	Oklahoma Corporation Commission	
Mr. Bob Griffith	Oklahoma Corporation Commission	(405) 521-4245

**APPENDIX B: Year-end Narrative
Oklahoma Corporation Commission
Underground Injection Control
Class II Wells
Work-plan 2015
7/1/2014-6/30/2015**

Oklahoma Corporation Commission (OCC) implemented a successful Program in FY 2015 meeting or exceeding most of the established targets outlined in Workplan 2015. The attached “Annual Report Card”, depicts a summary of Activities.

OCC currently has an inventory of approximately 11,600 active UIC wells.

Total UIC applications were at 661 for the year: 189 Disposals, 287 Injectors, 0 Annular, 0 SI, 47 Commercial Disposals, and 101 Exceptions to the rules, 14 Interim Orders, and 23 Emergency Orders. There were 591 UIC approved orders/permits this year: 141 Disposals, 280 Injectors, 0 Annular, 0 SI, 33 Commercial Disposals, and 109 Exceptions to the rules, 12 Interim Orders, and 16 Emergency Orders. Total number of dismissals was 116.

UIC inspections for 2015 were 11,725, which is higher than the 10,000 target. MIT’s numbered 2,956 this year.

In the area of GIS, UIC continues to sustain the OCC’s aerial photo library. We are current on all aerial photos from the NAIP. At this time we have county wide aerial photos for the years 1995, 2003, 2004, 2005, 2006, 2008, 2009, 2010, 2013, and 2014 in all 77 counties. These maps with well data are provided to our field inspectors, as the information is updated by our GIS specialist. All of this data is available to the EPA.

In addition to the aerial photos from NAIP, the georeferencing of archival photos is ongoing. This project has been aided by EPA through Special Project grants to purchase the needed ArcGIS license to georeference, and to hire temporary GIS specialist for georeferencing the OCC’s aerial photo library. All archival photos available at the Oklahoma State Library, NCRS, and Oklahoma Geological Society have been scanned and saved to the R Drive. OCC continues to obtain and scan aerial photos as they are located from various sources. Subsequent georeferencing of these photos produces historic time frames that can be used by UIC and the OCC in investigations. The aerial maps provide a more precise determination of well locations and a detailed record of past surface pollution. A total of 109,861 archival aerial photos have been scanned to date. This project is still in progress using OCC and UIC Special Project funds.

UIC staff continues to place an emphasis on the timely filing of 1012A forms (Annual Fluid Injection Reports) by operators in Oklahoma. Due to errors in both RBDMS and the 1012A report modules, UIC was unable to get accurate compliance data for 1012A forms. However, through the efforts of UIC staff, the errors are believed to have been corrected and missing 1012A forms have been reported to UIC Compliance. UIC is currently undertaking the necessary due diligence to obtain any missing 1012A reports, and expects 1012A compliance to return to it previous standards.

The Document Imaging Project has been successful. The well records in all four Districts have been imaged, and the PDF files made available in each district office. Currently, UIC is working on Phase II of this project. The goal of Phase II is to research the acquired imaged records, and compare them to the central OCC imaging database. Any missing records are then added to the central database. As of 6/30/2015, a total of 71,342 images have been reviewed and 2,584 of those images have been added to the central imaging database.

**Annual Report Card
UIC Program Activities
Workplan 2015
(7-1-14 through 6-30-15)**

Activity	Goals	Accomplishment
Inspections (On-site)	10,000	11,725
MITs (total)	2,300	2,956
MITs (Witnessed)	2,300	2,820
Permits (Total Issued)	NA	467
Technical Reviews	NA	518
Operatorship Transfers	NA	693*
Technical conferences	NA	350

**Number represents total 1073i forms processed per well, both approved and rejected*

The Oklahoma Corporation Commission (OCC), Oil and Gas Conservation Division has converted to the RBDMS database. RBDMS modules (including UIC) have been released, and are currently in production. OCC staff continues to review the modules for errors, make any needed corrections to RBDMS data, and develop updates to make the new database more user friendly for both OCC and the end users of our data.

APPENDIX C: RBDMS Issues
Ground Water Protection Council's (GWPC's)
Risk Based Data Management System (RBDMS)

GWPC's RBDMS database design allows modifications to meet specific Agency needs. In practice, this means that contractors essentially rebuild it into smaller components. Whether the database issues at OCC result from the RBDMS open system, OCC's requested customization or basic design is unclear.

With the advent of RBDMS, OCC UIC staff lost the ability to run their own database queries, but had to rely on assistance through an externally (state) sourced IT support group. These support staff work to provide assistance, but are hampered by data entry issues, lack of built-in program controls, and separate test and operational systems⁵.

A number of the identified issues may be resolved through consistent resolution (fixes) across the database as discussed in the first Database Mechanics section below. The Specific Program Issues section of this appendix covers the main issue, followed by specific program difficulties and potential fixes. The last section covers a few of the much needed standardized, flexible reports.

1) Database Mechanics

a) Consistent nomenclature

In order for the database to generate a report, the fields containing the critical data must be consistent. Consistent in this case, means both typed precisely the same way: spelling and capitalization. Consistency also applies to any search field, or summary field. Generally, the most reliable means of creating consistency is to use a drop-down list.

In order to link data between forms, there must be a defined method. A specific example is whether a well has an active permit. Currently, there is no reliable means to identify active permits in the database.

b) Correct data entry

Fields used for searching must be exact. For example, a permit or order number must match an actual numeric permit or order number. Currently, there are numerous case numbers miss-entered as order numbers.

i) Revising the API system

There are well API numbers entered with letters after them to indicate recompletions or sidetracks. All variations introduce difficulties in identifying the well location. The base number (State-County-Well or xx-xxx-xxxxxx) will always tie to the surface location. Recompletions will all have the same bottom hole location, but sidetracks or redrills may not. Additionally, three-legged laterals will have three separate bottom hole locations.

The PPDM well identification system is a future plan for OCC. It will require significant changes to get the current database realigned to accommodate this system. However, in the long run it will be extremely useful.

⁵ MIT queries have been periodically run on the test database rather than the live database.

ii) Order and Permit tracking

A system to track the active permit, and associated exception orders is required if MIT scheduling or automatic comparison of reported disposal volumes (F1012) with the permit conditions are desired reports.

Currently, there are no means to electronically identify which permits have expired, what orders have been replaced, amended, corrected or in some cases terminated. Termination information is tracked, but many of the orders entered are the replacement order not the one being terminated. Therefore, electronic tracking is not possible.

2) Specific Program Issues

a) Report to Schedule MITs

Mechanical Integrity Tests (MITs) are a fundamental and important part of the UIC program's purpose to protect of the Underground Source of Drinking Water (USDW). OCC reported almost a 1000 fewer MITs conducted in FY15 than FY14. In mid-December 2015, OCC discovered that 40% of their 380 commercial disposal wells were overdue for MITs. This backlog is primarily a direct result of ongoing issues with OCC's RBDMS. OCC reviewed several recent monthly MIT reports from RBDMS in order to schedule wells for MIT. This review revealed some specific concerns with the system.

To create a report of wells due for MITs, RBDMS compiles data from multiple entries relating to inspections, well classifications and current order information. For the past few years, the MIT query on RBDMS picked up numerous wells that have been temporarily abandoned or returned to production, wells that are not required to perform periodic MITs, while excluding many other wells actively injecting. Additionally, EPA identified numerous instances of operators receiving new permits (whether replacing an earlier order or an earlier permit) without a matching new MIT.

i) Well Classifications need drop-down list

OCC's previous data clean-up efforts in early FY15 focused on correcting 11,600 inaccurate well classifications. These inaccuracies resulted in part from two OCC entities using different code systems for the same well and typing errors during input of the code. Future problems of this nature could be largely resolved by development of a dropdown or preset list of choices for input.

ii) Inspection Types need drop-down list

A review of the October 2015 report created for scheduling MITs revealed additional data issues stemming from system requirements for UIC staff to enter inspection types for over 6500 records. The November 2015 report resulted in corrections to an additional 262 records. The December 2015 report contained over 860 well records with apparent data errors, including a number of well records previously corrected. This may have occurred as the query was run on the outdated test database not the real production database.

iii) Integrity Test Scheduling needs an active order connection, new fields, new forms and drop-down lists

In order to specify when the next MIT is due, it is necessary to know if one is required, when the last MIT was successfully passed, and the timing for the next test. This has several issues primarily related to missing requisite database mechanics:

- (a) An ability to track the current order and any exception orders.

- (b) There are no fields to specify the type and timing of the test(s).
 - (i) The location of stipulations on permits and orders are inconsistent.
 - (ii) Timing may be modified periodically through actions or directives, based on field findings or seismicity occurrence.
- (c) There is no method to electronically track whether the well successfully passed the MIT or other integrity tests.
- (d) There is no method to electronically track the type of test run.

Oracle, the previous data system, had the ability to indicate MIT due dates, however RBDMS does not. Instead, an entry option for MIT frequency requirement was only recently added. However, this information is entered manually by the field inspectors for each individual well. This is inefficient and conducive to errors.

b) Fluid Injection Reports

To demonstrate permit compliance, UIC well operators are required to file annual reports giving the monthly injection volume and associated injection pressure for their injection wells. OCC reports this information as 'monitoring and reporting' to EPA through OMB Form 7520. Analyzing this information, where sufficiently accurate, along with additional well mechanical and operational details, provides useful reservoir flow characteristics. Seismologists use the reported information as an integral part of their correlation between deep disposal well activity and seismic events.

Reporting problems include poor data reliability, multiple versions of apparently the same record and the inability to properly handle periodic and corrected reports, or reports on transfer of well ownership.

Initial efforts to load historic information into RBDMS resulted in multiple copies of the same report, along with coding issues that went undiscovered. UIC staff has spent many hours correcting these initial errors, as well as working with operators to file missing reports.

Despite significant improvements, repeated values in the database caused by corrected filings and multiple uploads can create inflated disposal volume reporting, which could result in invalid seismicity analysis.

i) Periodic Reports needs reprogramming with required fields, new fields and new forms

The current F1012A was designed for annual reports, without considering commercial wells biannual reporting, the need to file amended reports, or the need to require a report on transfer of ownership. It also did not consider separating the fluids disposed. Additionally in FY15, operators with disposal wells permitted in the Arbuckle Formation in defined Areas Of (seismic) Interest (AOI), were required to report daily injection pressures and volumes on a weekly basis.

Plans to allow RBDMS to accept daily operator volumes and pressures is in the works. However, this does not relieve operators from the annual reporting requirement.

Enhanced recovery wells permitted for water after gas will file two forms, one for each fluid (water and gas, which may not be CO2).

ii) Operator Filing

Operators have filed a small number of F1012s for wells with terminated orders. Unless the order termination was in same year the form covers, the filings were unnecessary.

(a) Daily Reports

If an operator is required to enter daily data, that information is needed for critical analysis. The analysis is not possible, if the volumes and pressures for the earlier part of the year are not available. Any filing of a daily report should trigger a request for either all the year in daily format, or the monthly reporting prior to inception of daily reports.

- Additionally, this should then replace the annual report through a computer generated version.

(b) Missing Records – need to interconnect 1073 with 1012s

Only recently has OCC required operators transferring ownership to file the F1012 for the partial year of the sale, i.e. there is a fair amount of missing data.

iii) Volume Tracking needs new field and a final report form

The input forms need to have a field to indicate whether it is a partial report (biannual, two week daily, partial year for multiple owners, corrected entry), or a complete annual report. OCC should decide how corrections are to be handled, i.e. whether the entire period needs to be reentered, or only the corrected data. Either option triggers a need for a corrected final well report to be created showing the correct volumes and pressures for the well.

Additionally, it is recommended for online views, that the computer show a calculated total volume, and a warning message if it does not match the entered total.

(a) Historic Errors – and a caution for current entries

If OCC needs old forms to be accurately accounted for, then additional work is required. Many operators entered the average daily rate for the month as opposed to the volume injected for the month. Some may still report this way!

The only way to identify which was entered is comparing the annual total volume to a sum of the monthly rates. Part of the issue is the form stating 'Rate', what precisely does that mean?

(b) Fluid used in total injection or disposal reports

Enhanced recovery wells, or storage wells (outside EPA jurisdiction) permitted for water after gas or gas only should only have the brine component added in the annual total. Gas (CO₂ or unspecified) should be summed separately.

iv) Data Reliability

The form (F1012a) has a blank for 'How was injection or disposal measured?' This appears to be auto-filled or defaulted to 'Calculated'. Any record with constant volumes (whether the equal monthly values or the equivalent same daily rate) is only an estimate. Ideally, this should be a drop-down list with computer override. Suggested choices include:

- Rate gauge only
- Pressure and rate gauge

- Estimated from tank volume
- Estimated volume and pressure
- Shut-in (all zeros)

OCC should also decide whether they will continue to accept all estimates, or whether permitted Arbuckle well input must accurately be measured.

v) Required data fields plus reformatting screen presentations

Revising the software to incorporate required data fields (well number, report year, report type: initial, semi-annual, correction) and to resolve several other fundamental issues such as lack of proper chronological order (by month) is necessary, but is not a simple coding problem.

(1) Actual last integrity test and a separate 'Comment' field

Additionally, the report and inspector form view must match. Currently, the inspector form has a field for comments, but the report view forces a last MIT due date.

Actually, this should be revised to include not only the last MIT, but whether or not it passed, as well as the last Radioactive Tracer or Water Level run. This may entail three different entries. Work with UIC staff and inspectors to revise the form.

2) Canned Reports

a) Create a MIT Schedules and overdue MIT report

Both District and Central offices need to be able to generate an accurate list of either overdue or upcoming MITs. Suggested options include:

- Overdue
- Due within 3 months
- Failed MITs
- By operator
- By District
- By type:
 - Radioactive Tracer
 - MIT

Working closely with OCC UIC staff and inspectors is highly recommended.

b) Create a canned customizable summary volume report

There should be an option for a summary report for volumes injected with a drop-down choice of how it is summarized:

- Grand total for year(s) or monthly for year(s)
- Total by county
- Total by Township-Range
- Total by Section-Township-Range

Additional choices may include:

- Arbuckle or deeper versus shallower
- Disposal, EOR or Commercial

Working closely with OCC UIC and Seismicity staff is highly recommended.

i) Other Procedural Issues

In late December, OCC discovered that 1000s of well locations had disappeared from the system, with no identified cause. During FY15, EPA had identified a number of instances where latitude and longitude were flipped or longitude was not entered as a negative, resulting in major discrepancies in spotting the associated wells. OCC's inspectors properly located disposal wells with GPS units, but the result of their efforts appears to have been lost through override from a later data input. This indicates the need for limited authority to change or delete prior entries.

Another procedural issue that could create delays in scheduling newly drilled and permitted wells for mechanical integrity tests, as well as inclusion in the active well count in seismically active areas, relates to timing of data entry. Apparently, the current procedure calls for adding new UIC well completions into RBDMS only after signing of the UIC permit or order. While this is logical, it creates the potential for the well to slip through the cracks and not get uploaded. This has in fact happened, showing up in a few cases when operators filed daily reports for wells RBDMS showed as not yet drilled or completed. When these cases are identified, the problems are resolved; however, the well location is not available until the completion report has been entered, making tracking seismicity and disposal operations even more difficult.

ii) Additional Capabilities Needed

As mentioned earlier, RBDMS needs a check and balance system to prevent accidental deletion of critical data, both for required field data and other records. This would involve defining authorization for changes. This would likely involve a complex software change.

OCC is actively working to reprogram RBDMS to accept electronic daily volume reports from operators. It is not in the current plan, but the new system should incorporate QA/QC checks to prevent some of the problems previously discussed, such as no duplicates, corrected data, verification of totals and accurate representation of whether the data is measured or estimated. The system planned for installation should include designated required data fields, as appropriate to ensure proper linkage with reports and other queries.

APPENDIX D: Operator Reporting Issues

Two Detailed Examples

Two specific examples of operator reporting issues follow.

1. Questionable data, despite operator's efforts—still not cleared up

An example of erroneous data not detected by field office verification: Devon reported the Harvey 1-11 SWD well as disposing no more than 40 barrels of water per day (BWPD). Yet Devon provided the following statement along with the appropriate water production volumes, "Harvey 1-11 MH well, which is the only producer injecting into the Harvey 1-11 SWD well." The water production volumes do not always match the filed official reported disposal volumes, with frequent disposal around 88 BWPD along with a handful of cases above 150 BWPD.

2. Failure to provide requested data, with no repercussions

Another case of inaccurate reporting occurred following the 2011 M5.7 earthquake near Prague, OCC requested detailed information from New Dominion on the Wilzetta SWD well. At the time OCC, considered this well an unlikely candidate for involvement in the earthquake, since disposal was by vacuum (no surface injection pressure) and the reported injection zone above the basement. Current information indicates fluids disposed into this well could have flowed directly into the basement rock.

- The SWD application includes an October 1999 letter stating, 'This well is drilling, but when completed, a copy of the open hole logs and cement bond log will be sent to the UIC Department as soon as possible.'
- The F1002A filed 9/25/99, stated the Wilzetta SWD 1 was completed in the Wilcox 1, 2 and Arbuckle between 4470-6725'. The top of the Arbuckle was given as 4925'.
- Open hole logs before the casing was set, were filed, but nothing was filed after the rest of the well was drilled following casing installation--therefore no information on the open hole section used for disposal was filed.
- In May 2015, following OCC's plugback directive, New Dominion filed the following:
 - A spectral density log (run 9/19/99) run to 7000', showing the Wilzetta SWD 1 was drilled almost 200' below the base of the Arbuckle.
 - F1085 filed 5/28/15, '5-28-2015 Plugged Arbuckle Disposal from 6841 to 6662'.
- On 6/23/15, New Dominion filed a corrected F1002a for the total depth and plug back depth. However, the total depth reported was not changed and therefore does not reflect the correct logger's depth.
 - 'PLUG BACK WILZETTA SALT WATER DISPOSAL PER OCC LETTER DATED MAY 18, 2015. OCC REPRESENTATIVE ROGER PEARMAN WITNESSED PLUG BACK AND APPROVED MAY 28, 2015. OCC - ARBUCKLE IS AN OPEN HOLE COMPLETION FROM BOTTOM OF THE 9 5/8" CASING AT 4,920' TO TOP OF PLUG BACK AT 6,662'. UIC ORDER NUMBER 617666'

APPENDIX E: M4+ Events
Oklahoma Geologic Survey Catalog
Earthquake Events >= M4 (preferred magnitude)

id	DateT	latitude	longitude	Depth (km)	county	Origin src	Pref mag	Pmag type	Pmag src	Ml ogs
12951	2014-07-12 T17:11:47.47	35.86215	-97.32444	4.047	LOGAN	OGS	4	MW	USGS	4.3
13198	2014-07-29 T2:46:36.36	36.75605	-98.04534	5.287	GRANT	OGS	4.3	MW	USGS	4.4
13445	2014-08-19 T12:41:36.36	35.77268	-97.46767	4.923	LOGAN	OGS	4.4	MW	USGS	4.3
13940	2014-09-30 T3:01:26.26	36.22347	-97.55351	2.2	GARFIELD	OGS	4	MW	USGS	3.9
14083	2014-10-07 T16:51:13.13	35.94777	-96.76562	5.28	PAYNE	OGS	4	MW	USGS	4
14162	2014-10-10 T13:51:21.21	35.94664	-96.75941	5	PAYNE	OGS	4.2	MW	USGS	4.5
15137	2014-11-30 T10:24:44.44	36.60262	-97.60654	5.684	GRANT	OGS	4	MW	USGS	4.3
15452	2014-12-14 T21:18:21.21	36.31673	-96.7557	4.679	PAWNEE	OGS	4	MW	USGS	4.2
16201	1/27/15 11:31 AM	36.26183	-97.26426	3.408	NOBLE	OGS	4.2	MW	USGS	4.1
16208	1/27/15 3:58 PM	36.62881	-97.71238	2.951	GRANT	OGS	4	MW	USGS	4
21466	2/3/15 12:37 PM	36.81357	-98.28722	4.516	ALFALFA	OGS	4	ML	OGS	4
16346	2/5/15 3:08 PM	36.8144	-98.28503	4.381	ALFALFA	OGS	4.2	MW	OGS	4.6
16940	3/17/15 11:45 PM	36.59946	-97.62216	2.381	GRANT	OGS	4	MW	OGS	3.9
17038	3/23/15 11:29 PM	36.63361	-97.65393	2.588	GRANT	OGS	4	MW	OGS	4.1
17059	3/24/15 7:48 PM	36.77765	-98.0301	6.513	GRANT	OGS	4	MW	OGS	4
17353	4/4/15 1:21 PM	36.11762	-97.57166	5.047	LOGAN	OGS	4.1	MW	US	4.3
17428	4/8/15 8:52 PM	35.81786	-97.41911	2.487	LOGAN	OGS	4.3	MW	OGS	4.1
21473	4/19/15 5:27 AM	35.92153	-97.32819	4.738	LOGAN	OGS	4.1	MW	OGS	4.3
17731	4/27/15 10:22 PM	35.9199	-97.32759	5.279	LOGAN	OGS	4.1	MW	US	4.1
18441	6/14/15 6:17 PM	36.28617	-97.52208	6.278	GARFIELD	OGS	4	MW	US	4
18497	6/17/15 7:17 PM	36.28568	-97.52354	6.008	GARFIELD	OGS	4.3	MW	US	4.3
18550	6/20/15 5:10 AM	35.73917	-97.3865	3	LOGAN	OGS	4	MW	US	4.1

id	DateT	latitude	longitude	Depth (km)	county	Origin src	Pref mag	Pmag type	Pmag src	Ml ogs
18996	7/20/15 8:19 PM	36.84342	-98.25707	4.079	ALFALFA	OGS	4.4	MW	US	5
19156	7/27/15 6:12 PM	35.98888	-97.57169	5	LOGAN	OGS	4.5	MW	US	
19114	7/28/15 1:18 AM	35.99086	-97.58134	5.253	LOGAN	OGS	4.1	MW	OGS	4.6
19410	8/14/15 9:25 PM	36.83698	-97.80936	0.091	GRANT	OGS	4.1	MW	US	4.4
20132	9/18/15 12:35 PM	35.98925	-96.79565	0.208	PAYNE	OGS	4.1	MW	US	4.1
20250	9/25/15 1:16 AM	35.98717	-96.78739	2.893	PAYNE	OGS	4	MW	US	4.2
20541	10/10/15 9:20 AM	36.71896	-97.9306	5.629	GRANT	OGS	4.4	MW	US	4.7
20543	10/10/15 10:03 PM	35.8841	-97.00651	3.274	LINCOLN	OGS	4.4	MW	US	4.2
20934	11/7/15 11:11 AM	36.95278	-97.85525	5	GRANT	OGS	4.1	MW	US	4.3
21034	11/15/15 9:45 AM	36.46884	-98.7554	5.109	WOODS	OGS	4.3	MW	OGS	4.6
21083	11/19/15 7:42 AM	36.66024	-98.45942	5.917	ALFALFA	OGS	4.7	MW	US	5.3
21111	11/20/15 10:40 PM	36.94833	-97.82757	5	GRANT	OGS	4.1	MW	US	4.5
21126	11/23/15 9:17 PM	36.83823	-98.27615	5.028	ALFALFA	OGS	4.4	MW	US	4.8
21427	11/30/15 9:49 AM	36.76373	-98.05417	2.271	GRANT	OGS	4.7	MW	US	4.9
21476	12/29/15 11:39 AM	35.66543	-97.40543	6.532	OKLAHOMA	OGS	4.3	MW	US	4.5

APPENDIX F: Seismic Data Sensitivity Relocation and Magnitude Calculations

Recalculating the magnitude based on a combination of surface readouts and surface damage includes a choice of different calculation methods. This later can be subjective, with most seismologists agreeing that the energy calculation methods are more accurate for larger earthquakes than the local or Richter scale. The discrepancies come in deciding when to switch methods, which variation of the formula and the specific parameters to use.

Figure 3 illustrates the subjectivity, though some of the variability between the USGS and OGS values, below M3, may be due to seismometer density. Over the same timeframe, using their respective preferred method's OGS (as of December 2, 2015) identified 41 events M4+⁶ versus the USGS 44 events. OGS using the (less accurate) Richter or local method identified 73 M4+ and 2 M5+ events.

The result of the above factors is a moving target for OCC when identifying M4+ events, even without location discrepancies. It is EPA's understanding, that OGS runs the preliminary computer analysis of earthquake events through a second check prior to releasing the information in their online catalog. This resulted in three-day delay in identifying 16 seismic events after the Thanksgiving weekend. Recalculating one of these to M4.5 (from below M4) took a week.

Currently OGS has no mechanism to identify updated/revised events in their earthquake catalog. This means downloading the catalog at different times will give different results, and using daily updates will not incorporate any corrections. Additionally, the relocation files provided to OCC do not contain metadata (key parameters used in the calculations). The two files, dated respectively 6/26/15 and 9/29/15, have noticeably different event locations, but no indication as to why, see Table 1.

Table 1: Event on 6/26/2015 T10:49:58.81

File	longitude	latitude	depth	magnitude
June 26	-97.380363	35.740344	4.519	3.4
Sept. 29	-97.381038	35.739998	5.371	3.4

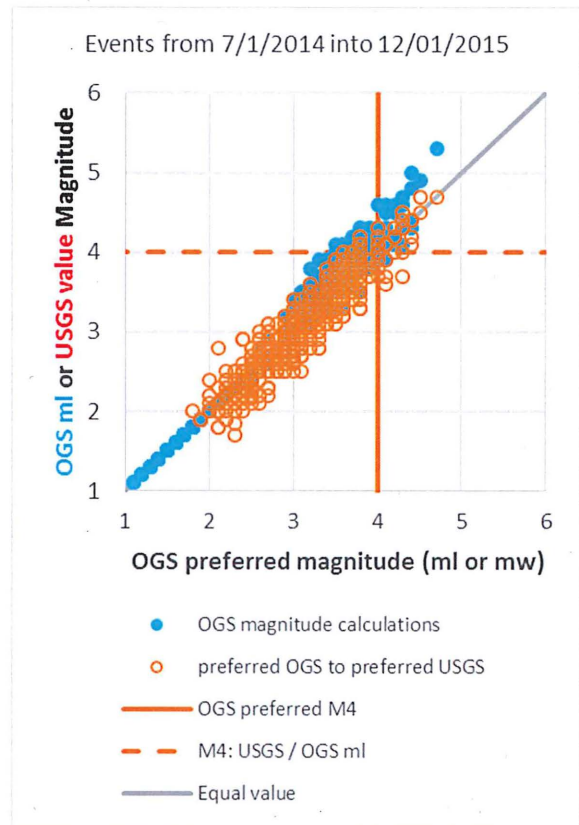


Figure 6: Magnitude Calculations

⁶ M4+ means an event with a magnitude of greater than or equal to 4

APPENDIX G: Seismicity Actions and Directives
Oklahoma Corporation Commission
Directives and Actions with respect to Seismicity

The "traffic light" system was first put in place by the Commission in 2013 in response to concerns over the possibility of earthquake activity being caused by oil and gas wastewater disposal wells in Oklahoma. The "yellow light" permitting program requires seismicity review for any proposed disposal well and requires special permitting based on seismicity concerns to any well proposed within 3 miles of a stressed fault, even in the absence of seismicity and any proposed disposal well within 6 miles (10 kilometers) of an earthquake "swarm" or magnitude 4.0 event.

The numerous OCC actions and directives taken in response to seismicity are available for public viewing on the State's new seismicity resource: Earthquakes in Oklahoma (<http://earthquakes.ok.gov/>). An outline of the major findings, actions and directives for 2015 up through November follows, (for complete details please refer to website). Appendix D lists all OGS events with a preferred magnitude greater than or equal to 4, since the start of FY2015 through the end of November, 2015.

1. 10/10/2014 Cushing Operational Restrictions
 - a. Events: 10/7 and 10/10 M4.2
 - b. Conversations with operators, one well shut-in (Wildehorse SWDW 1).
 - i. Plugged back out of granite on 10/16/14 and returned to disposal.
2. 1/30/2015 Extension of Traffic Light System
 - a. New permits in Area of Interest (AOI) require a court hearing and have a maximum 6 month term aka an Interim Order.
 - b. AOI defined as within 3 miles of a stressed or seismically active fault; or within 6 miles of a M4.
 - c. Annual MIT for high volume wells and increased disposal reporting (daily).
3. 3/25/2015 Redefined Yellow Traffic Light AOI for Arbuckle disposal wells
 - a. AOI defined as within 10 km of earthquake swarm center, (347 Arbuckle wells included).
 - b. Proof that disposal is within the Arbuckle (not deeper), **or** reduce disposal rate by half.
 - c. Compliance within 60 days, (April 18).
4. 4/21/2015 Launch of Earthquakes in Oklahoma and release of Oklahoma Geologic Survey findings on triggered seismicity.
5. 7/17/2015 Increased Yellow Traffic Light AOI
 - a. Area increased to 122 square miles, 558 Arbuckle wells included).
 - b. Reduced rate for below Arbuckle removed, wells to be shut-in or plugged back.
 - c. Compliance by August 14.
6. 7/28/2015 Crescent Area Operational Restrictions
 - a. Events: 7/27 M4.5 & 7/28 M4.1 in Logan Co.
 - i. 4/4 M4.1
 - b. Operator agreed action: Two wells shut-down and one well with 50% reduced volume
 - i. One well (Hopfer SWD 1-20) was plugged back out of granite on 10/13 and brought back on at half volume; the second (Chambers 1-8 SWD) was allowed to come back on one month later (8/25) at a half volume.
7. 8/3/2015 Logan County Trend Reduced Volume Plan
 - a. Definition of a small (initial test area) in northern Oklahoma and southern Logan county that is very seismically active.

- i. Ten M4-M4.3 events between 12/29/2013 and 6/20/2015.
 - ii. An eleventh M4 on 11/02/15
 - 1. One interim order well (Lenora 29-18N-1W 1SWD) shut-in.
 - b. Required operators to reduce disposal volumes by 38% below total 2012 level.
 - c. Compliance by October 8.
- 8. 8/27/2015 Revised 165:10-5-7 rules
 - a. Operator gives notice within 48 hours for initial Arbuckle disposal operations.
 - b. Record Arbuckle disposal operations daily for volumes, casing tubing annulus pressure and the surface injection pressure.
- 9. 9/18/2015 Cushing Area Operational Changes
 - a. Event: 9/18 M4.1
 - b. Proximity of increased earthquakes to tank farm, along with a M3.7 prompted actions.
 - i. The M4 was not posted until a month later on a revised catalog.
 - c. Conversations with operators, one well shut-in (Wilson 11-1 SWD), and one in granite (Louis 6-3 SWD) in and three others with reduced volumes.
 - i. Wilson still shut-in (question as to total depth), Louis plugged back on 10/5/15 and returned to operation.
- 10. 10/19/2015 Increased Cushing Operational Restrictions
 - a. Events: 9/25 M4.2 and 10/10 M4.3
 - i. In 2015: 73 events of M2.5 or greater within 3 miles
 - b. Arbuckle wells within 3 miles are shut-in. Three more shut-in (Calyx 35-2; Etheridge 25-3; Joyce A1-20 SWD)
 - i. One well (Joyce A 1-20) will be recompleted to the Wilcox, others remain Shut-in.
 - c. Arbuckle wells between three and six miles reduce disposal volume by 25%.
 - d. Operators of Arbuckle wells between six and ten miles are on notice of potential changes if seismicity continues.
- 11. 11/10/2015 Medford Area Operational Restrictions
 - a. Events: 11/07 M4.1 and another 11/20
 - i. In 2015: 21 events of M2.5 or greater within 3 miles
 - 1. 37 within 3 to 6 miles
 - 2. 314 between 6 and 12 miles
 - b. Arbuckle wells within 3 miles reduce disposal volume by 50%.
 - c. Arbuckle wells between three and six miles reduce disposal volume by 25%.
 - d. Operators of Arbuckle wells between six and ten miles are on notice of potential changes if seismicity continues.
 - e. One well (Thomas 1-27) required to shut-in until plug back into Arbuckle completed.
- 12. 11/16/2015 Fairview Area Operational Restrictions
 - a. Arbuckle wells within 3 miles – there are none.
 - b. Arbuckle wells between three and six miles reduce disposal volume by 25%.
 - c. Operators of Arbuckle wells between six and ten miles are on notice of potential changes if seismicity continues.
 - d. One well (Rich 1-32) required to shut-in until plug back into Arbuckle completed.
- 13. 11/19/2015 Cherokee-Carmen Area Operational Restrictions (corrected)
 - a. Two Arbuckle wells (McDaniel SWD 1-18; Dutch Harbor SWD 1-14) within 3 miles are shut-in.
 - i. Dutch Harbor was plugged back on 10/1/15.
 - b. Arbuckle wells between three and six miles reduce disposal volume by 50%.

- c. Operators of Arbuckle wells between six and ten miles reduce disposal volume by 25%.
 - d. Operators of Arbuckle wells between ten and fifteen miles are on notice of potential changes if seismicity continues.
 - e. Net 40% volume reduction to be achieved.
14. 11/20/2015 increased Crescent Area Operational Restrictions
- a. Events: 11/2 M4; 11/19 M3.6 (M4.1 ml)
 - i. Earlier events: 4/8 M4.3 and 4/27 M4.1
 - b. Arbuckle wells within 3 miles are shut-in.
 - i. Three wells were shut-in (Krittenbrink 1-36 SWD; Vonda SWD 1-6; Adkisson 1-33 SWD).
 - c. Arbuckle wells between three and six miles reduce disposal volume by 50%.
 - d. Operators of Arbuckle wells between six and ten miles are on notice of potential changes if seismicity continues.
15. 12/03/2015 Byron-Cherokee and Medford Area Operation Restrictions
- a. Events: 11/23 M4.4; & 11/30 M4.5, with 10 mile buffers overlapping
 - i. Earlier: 2/5 M4.2; 3/24 M4; 7/20 M4.4; 8/20 M4.1
 - b. Arbuckle wells within 3 miles are shut-in.
 - i. Four wells in the Byron area (Diamondback SWD 2710 1-5 & 2-5; Lidia SWD 2710 10-7; Tatum Rose SWD 2710 2-17) and
 - ii. Three wells in the Medford area (Harley SWD 1-11 & 2-11; George 1 SWD) were shut-in.
 - c. Arbuckle wells between three and six miles reduce disposal volume by 50%.
 - d. Operators of Arbuckle wells between six and ten miles reduce disposal volume by 25%.
 - e. Operators of Arbuckle wells between ten and fifteen miles are on notice of potential changes if seismicity continues.
 - f. Compliance by December 30th for reduced disposal, by December 9th for shut-in.

